Factors Affecting the Likelihood of Corn Rootworm Bt Seed Adoption

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Abstract

The likelihood of adopting corn rootworm (CRW) Bt seed technology was analyzed using an ordered logit model. Data used to estimate the model came from USDA's 2001 Agricultural Resource Management Survey. Statistically significant variables include operator age, farm type, farm size, rootworm loss and current treatment for rootworm, off farm labor, and Bt technology for corn borer. The likelihood of adoption was not related to crop rotation, tillage system, new variant CRW region, or education.

Keywords: Corn rootworm, Bt seed technology, Agricultural Resource Management Survey (ARMS), ordered logit model.

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Introduction

Bioengineered (BE) seed with an insect-resistant trait has been one of the most rapidly adopted technologies by U.S. corn producers. Between 1995, when BE corn seed for European corn borer control became widely available, and 2002, adoption grew to 24 percent of U.S. planted corn acreage (USDA-NASS 2002). In some states, use of BE corn seed exceeded 40 percent in 2002. As of 2003, a new commercially available BE seed variety is corn seed carrying a gene from the soil bacterium Bt, *Bacillus thuringiensis* selected for resistance against the corn rootworm (CRW), which is believed to be an even more destructive corn insect pest than European corn borer. Entomologists estimate that this pest causes at least $1 billion in corn yield losses and insecticide expenditures annually in the U.S. (Coomis 1997). The widespread adoption of CRW Bt seed could have substantial impacts on farm income, costs of production, productivity, insecticide use, and the environment. Many of the insecticides currently used for CRW control are organo-phosphate based and pose serious human health and environmental risks. Adoption of Bt seed technology would reduce these risks. However, despite these benefits, BE seeds, including CRW Bt, remain controversial. Issues include consumer choice, food safety, and environmental impact. Therefore, the extent of likely CRW Bt adoption and the farm-level factors affecting CRW Bt adoption are important research and public policy topics.

Objectives

The objectives of this paper are: 1) to present the results of a 2001 farm level probability-based survey of corn producers in the major U.S. corn growing states who were asked about their likelihood of adopting CRW Bt seed when it becomes available, and 2) to present the results of a ordered logit analysis that identifies the operator and farm socio-economic characteristics and insect management practices that influence the likelihood of CRW Bt seed adoption.

Background

Corn is one of the most important crops grown in the United States. In 2001, corn was planted on 75.8 million acres with a harvested value of over $19.2 billion (USDA-NASS). This represents over 21 percent of the total value of crop production in the U.S. for 2001.

CRW is probably the most economically important pest infesting corn in the United States. Historically, farmers managed CRW by rotating crops or insecticide use. The most common rotation scheme is corn-soybeans. Crop rotation had the effect of breaking the CRW life cycle--CRWs that hatched the following spring in a non-corn field would starve to death. Almost 67 percent of all corn acres are in a traditional corn-soybean rotation, while 14 percent are in continuous corn and the remaining acres are in other rotation systems (ARMS 2001). However, different species of CRW have apparently evolved to reduce the effectiveness of crop rotation as a pest control practice. For example, the Northern CRW began laying eggs that take 2 years to hatch. Beginning in the mid 1990s, farmers in east-Central Illinois and northern Indiana began noticing a reduction in the effectiveness of crop rotation in controlling Western CRW. Adult Western CRW beetles were leaving the cornfields to lay eggs in soybean fields. When the eggs hatched the following year, they were in a cornfield. These new variants of CRW have spread though most of northern Indiana and east Illinois and into southern Michigan and western Ohio. Given historic movement patterns, the new variants may soon spread as far west as eastern Iowa (Onstad 1999).

In cases where crop rotation is not widespread, farmers often use soil insecticides to control CRW. Based on 2001 ARMS data, about 18 percent of all corn acres in 2001 were treated for CRW with insecticides. Producers growing continuous corn had a much higher incidence of soil insecticide use, with about 38 percent of these acres treated with insecticides for CRW (more than double the share for corn-soybean or other rotations). With the loss of crop rotation effectiveness, corn farmers will have to either increase their use of soil insecticides or turn to other CRW control methods. One option, which became commercially available in early 2003, is the use of seed containing Bacillus thuringiensis (Bt), a natural occurring bio-toxin derived from soil bacterium that provides resistance to CRW.

CRW Bt as an Alternative

Bt is an insecticidal protein that provides protection from specific insects. This protection is generally greater than the most optimally applied conventional insecticide. Bt proteins are not toxic to people or animals and they have fewer negative environmental impacts than synthetic pesticides. In February 2003, the U.S. Environmental Protection Agency (EPA) approved a seed corn variety that contains the Cry3Bb protein for use. This protein specifically targets the mid-gut lining of larval rootworms. In trials, Bt seed yield outperformed both untreated fields and fields treated with conventional soil insecticides (Burchett 2001).

Use of Bt seed technology has multiple benefits to the farmer. These include convenience, reduction in cost, and reduction in labor. The main effect of using Bt seed technology is increased coverage (each individual plant is protected), resulting in reduced insecticide and labor costs and increased yields (relative to non-Bt fields that are infested with CRW). Bt seed use has the additional advantages of decreasing insecticide use in general and reducing cost and risk to the farmer or farm-worker who applies the insecticide. A major drawback to Bt seed technology is the current lack of acceptance of BE products in the European Union (EU) and, consequently, other countries that trade heavily in agricultural products with the EU. Lack of acceptance of Bt corn in the international marketplace could force some additional costs onto the farmer by increasing management efforts to segregate the crops. In general, crops not acceptable for trade are fed to local livestock. Other drawbacks include increased seed cost to the farmer and increased management time.

With crop rotation losing its effectiveness as a CRW control, the primary alternative to Bt technology becomes traditional insecticide use. Over 9 million pounds of insecticide were applied to the 2001 corn crop. Soil insecticides are generally broad spectrum (i.e., they target more than one pest) and are effective, but they also have the potential for negative effects on the environment and often pose risks to human and animal health. In contrast, CRW Bt seed is pest specific and effective, and, according to the EPA, does not pose an unacceptable health or environmental risk. In addition, an option is a “stacked” variety (such as Pioneer YieldGard + LibertyLink – a seed genetically modified for both herbicide and insect resistance) to make Bt seed effectiveness broader. There are currently no stacked corn varieties approved by the FDA and EPA that target multiple insects, although research is ongoing.

Adoption of Bt technology to combat corn borer may have been limited due to the unpredictability of outbreaks. Farmers may have chosen to plant non-Bt corn, gambling that there would not be an infestation. Even so, by 2002, adoption grew to 24 percent of corn planted acreage. This unpredictability problem does not exist in relation to CRW. Farmers can predict the need to treat for CRW based on current year populations (Gray and Steffey, 2002). Given this difference, the adoption of Bt technology to deal with CRW may be more rapid than that to control corn borers.

Technology Adoption

Technological change, which is intertwined with the adoption of innovations, underlies the growth in agricultural productivity (Sunding and Zilberman, 2001). Much of the previous literature on technology adoption has focused on mechanical (e.g., tractors), chemical (e.g., pesticides), and agronomic (e.g., IPM) innovations. More recent research has been devoted to informational (e.g., precision farming) and biological (e.g., GE) innovations (Feder, et al., 1985; Daberkow and McBride,; Fernandez-Cornejo et al., 1994; Fernandez-Cornejo and McBride). Many of these adoption studies assess the factors that affect if and when a specific farm or operator will begin to use an innovation. The most common factors analyzed have been expected profitability, risk, required skill level or education, scale or size of farm, alternative or competing technologies, enterprise specialization, information sources, credit availability, tenure, and environmental policies (Sunding and Zilberman). More recent studies have examined the hypothesis that off-farm labor within a farm household may also influence the decision to adopt a new technology (Fernandez-Cornejo and Hendricks).

Modeling Adoption Choices

The adoption of a new technology is usually modeled as a choice between two alternatives, the traditional technology and the new one. Growers are assumed to make their decisions by choosing the alternative that maximizes their perceived utility (Fernandez-Cornejo et al., 1994). Thus, a grower is likely to adopt new technology if the utility of adopting, U_{a1}, is larger than the utility of not adopting, $U_{a0,}$ that is if: $U_a^* = U_{a1} - U_{a0} > 0$. However, only the binary random variable I_a (taking the value of one if the technology is adopted and zero otherwise) is observed, as utility is unobservable:

(1)
$$Y_i = \begin{cases} 1 \text{ if } U_{i\,1}^* = \text{Max } (U_{i\,1}^*, U_{i\,0}^*) \\ 0 \quad \text{otherwise.} \end{cases}$$

Moreover, because utilities are not known to the analyst with certainty, they are treated as random variables. In the context of adoption of a bioengineered crop: $U_j = V_j + \varepsilon_j$, where V is the systematic component of U, related to the profitability of adopting (j=1) and the profitability of not adopting (j=0), and the random disturbance (ε) accounts for errors in perception and measurement, unobserved attributes and preferences, and instrumental variables.

The probability of adopting is:

$P_1 = P\,(I = 1) = P\,(U^* > 0) = P\,(U_1 > U_0) = P(V_{i1} - V_{i0} > \varepsilon_0 - \varepsilon_1) = P(\varepsilon_0 - \varepsilon_1 < V_1 - V_0)$.

Assuming that the stochastic components e_{i1} and e_{i0} are independently and identically distributed with a Weibull distribution, then their difference follows a logistic distribution (Maddala).

Assuming a linear utility function and that choice probabilities only depend on observed individual-specific characteristics (Judge and others), the relative odds of adopting are:

(2)
$$P_1/P_0 = \exp\,(\alpha + \delta' Z)$$

where the odds ratio (P_1/P_0) denotes the ratio of the probability of adopting the bioengineered crop to the probability of not adopting, conditional on the vector Z of explanatory variables; α is the intercept parameter and δ_a is the vector of slope parameters. Taking the log of each side, the logit equation is:[1]

$$\log (P_1/P_0) = \alpha + \delta' Z \qquad (3)$$

Unlike actual adoption, which is usually represented by a binary choice model, the expected adoption may be represented as an ordinal response model, where the response, I of a farmer is restricted to one of a small number of ordinal values. For example, in the particular case of adoption of Bt corn to control the CRW, we have specified (see survey question in the next section) 5 ordinal choices, j = 1, 2…5. Considering the cumulative probabilities of the response categories, the cumulative logit model may be represented with a slight modification of equation (3) setting a parallel-lines regression model in which, instead of one intercept (α), we will have four intercepts ($\alpha_1, \alpha_2, \alpha_3$, and α_4) together with the common vector of slope parameters Z.

Survey Data and Estimation

The data used to estimate the ordered logit are from USDA's Agricultural Resource Management Survey. ARMS is USDA's primary vehicle for collecting data on a broad range of issues about agricultural resource use, costs of production, and farm financial conditions. ARMS is a flexible data collection tool with several phases, versions, and uses. The ARMS is designed to meet four goals: 1) gather information about the relationships among agricultural production, resources,

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[1] For continuous variables, the change in the probability of adoption relative to the change of the kth individual attribute is

$$\frac{\partial P_1}{\partial Z_K} = f(Z) = \frac{e^{-\delta Z}}{(1 + e^{-\delta Z})^2} \bullet \delta_K \qquad (2)$$

In the discrete case, the change in probability attributable to the kth variable or attribute is equal to the difference in probability
$P_1 (Z_k = 1) - P_1 (Z_k = 0)$ (Putler and Zilberman).

and the environment; 2) estimate costs associated with the production of various crop and livestock commodities; 3) estimate net farm income; and 4) estimate the characteristics and financial situations of farm/ranch operators and their households, including information on management strategies and off-farm income. The ARMS is a series of related farm surveys that provide primary data for these functions. The phase I survey is a mail/telephone screening instrument designed to improve survey efficiency. Phase II is a series of commodities surveys conducted to obtain mostly physical data on production inputs, practices, and costs for specific crops. Phase III is designed to represent all U.S. farms and mostly focuses on farm operation characteristics, farm expenditures and receipts. Farms in the phase II surveys are automatically selected for a follow-on questionnaire in Phase III (the commodity cost of production surveys) and the information from both surveys can be linked and used to represent the population of all producers of a specific commodity or all U.S. farms.

The data used in this study are from farms that planted corn during 2001. The states included in the survey accounted for 93.4% of the U.S. corn acreage planted in 2001. The ARMS is a multi-frame, probability-based survey in which sample farms are randomly selected from groups of farms stratified by attributes such as economic size, type of production, and land use. Within a stratum, the weight (expansion factor) is the inverse of the probability of its selection.
After selecting those farms in the sample that planted corn in 2001 and eliminating those observations with missing data, there were 1,587 observations available for analysis.

This analysis is unique in that we examine the expected, as opposed to actual, adoption of an innovation. Since CRW Bt was not available for commercial use in 2001, producer's expectations about their likelihood of adoption were based primarily on their exposure to pre-commercialization information and familiarity with similar technology. In the case of CRW Bt, popular magazines and public notices of regulatory applications for commercialization were the most likely sources of early information about CRW Bt. Bt corn seed to control European corn borer is a similar technology to CRW Bt and had been commercially available for 7 years prior to the 2001 survey. Corn producers' expected adoption of CRW Bt seed was obtained in the 2001 ARMS by asking the following question: If a CRW Bt seed becomes available, how likely would you be to plant it on this field: 1=very likely, 2=somewhat likely, 3=uncertain, 4=somewhat unlikely and 5= very unlikely. Producers would not have available a critical piece of economic data, the price of CRW Bt seed, when responding to this question, but they likely made the assumption that the additional cost of the CRW Bt seed would be similar to the cost of a soil insecticide application or the additional cost of European corn borer Bt seed over regular seed.

The choice of factors hypothesized to influence producer's likelihood of CRW Bt adoption was based primarily on earlier research on innovation adoption (Table 1). Human capital variables, age and education, were included as were two farm characteristics, farm size (in acres) and specialization in corn production. A competing pest control option, crop rotation, was also included as a dummy variable (i.e., equal to one if the farm does not rotate, implying that it plants corn continuously). Previous studies have identified perceived risk and lack of information about an innovation as a barrier to adoption. Hence, we included a variable to control for the operator's use of a similar technology (i.e., Bt corn to control for European corn borer). Since CRW levels may be influenced by tillage system, according to some entomologists, we included a control variable for tillage system (Bessin 2001). As an indication of the benefit from adopting CRW Bt seed, we included several variables: the expected degree of pest infestation measured as the anticipated CRW losses (bushels) without treatment for CRW; whether an insecticide is currently used to control for CRW; and two location variables. The first location dummy variable, NEWVARIANT, was equal to one if the farm is located in counties where the new variant of CRW is able to survive crop rotation[2]. The second location variable, EAST, controls for the fact that farmers in areas where a higher proportion of the corn is sold for the export market are less likely to adopt technologies that may cause concerns in those markets. The export market is more important to major corn producers in the eastern corn-belt (IL, IN, and OH) than to producers in the rest of the country. All 3 eastern corn-belt states are in the top 10 corn producing states and exports account for slightly more than 31 percent of corn production in these three states compared to 21.3 percent in the other seven (Fruin 1985). Finally, we included a variable for household (spouse and operator) off-farm employment to account for the level of management time available to learn about new production technologies.

Because of the complexity of the survey design, a weighted technique was used to estimate the parameters of the ordered logit model using a maximum likelihood method and full-sample weights developed by the National Agricultural Statistics Service (NASS) of the USDA. A

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[2] Counties include: Illinois - Champaign, Christian, Coles, De Kalb, De Witt, Douglas, Edgar, Ford, Grundy, Iroquois, Kane, Kankakee, Kendall, La Salle, Lee, Livingston, Logan, McLean, Marshall, Mason, Moultrie, Ogle, Peoria, Piatt, Putnam, Sangamon, Shelby, Tazewell, Vermilion, Warren, Will, Woodford; Indiana – Adams, Allen, Benton, Blackford, Boone, Carroll, Cass, Clinton, De Kalb, Delaware, Elkhart, Fountain, Fulton, Grant, Hamilton, Hancock, Hendricks, Henry, Howard, Huntington, Jasper, Jay, Johnson, Kosciusko, Lagrange, Lake, La Porte, Madison, Marion, Marshall, Miami, Monroe, Montgomery, Newton, Noble, Parke, Porter, Pulaski, Putnam, Randolph, Rush, St. Joseph, Shelby, Starke, Steuben, Tippecanoe, Tipton,

delete-a-group jackknife method was used to calculate the variances and standard errors because of the survey design and because the conventional variance formulas do not apply to this type of model (Lee, Maddala, and Trost). The method follows the logic of the standard jackknife method except that a group of observations is deleted in each replication (Dubman, 2000). It consists of partitioning the sample data into r groups of observations (r = 15 in this survey) and re-sampling; thus forming 15 replicates and deleting one group of observations in each replicate (Rust; Kott; Kott and Stukel). A set of sampling weights was calculated by NASS for each replicate.

Results

The results from this process relate to farms and not to corn acres. No attempt was made in the survey to determine if a farmer would plant both Bt and non-Bt seed (exclusive of the required refuge area). Thus, we were unable to estimate the acreage that would be planted to CRW Bt. Tables 1 and 2 present the results from the statistical analysis of the survey data. Table 1 provides the mean values of the variables used in the ordered logit analysis. For a binary indicator variable, the mean represents the percentage of growers of each group with that attribute. For example, the NOTILL variable indicates that 17.5 percent of the farmers used no-till. In comparison, the continuous variables represent the actual means. For example, OP_AGE represents the mean operator age, 52 years. Table 2A. presents the means of the categorical dependent variable, EXPTADOP. Overall, about 15 percent of the corn producers in the sample were very likely to adopt CRW Bt, nearly 20 percent were likely to adopt, 25 percent were uncertain, nearly 12 percent were somewhat unlikely to adopt, and about 28 percent were very unlikely to adopt.

Vermillion, Wabash, Warren, Wayne, Wells, White, Whitley; Michigan – Berrien, Calhoun, Cass, Huron, Kalamazoo, St. Joseph, Van Buren.

Table 3 presents the ordered logit regression results for the expected adoption of Bt corn to control the CRW. The overall goodness of fit is very good and the classification accuracy is about average compared with other adoption studies. For example, using the transformed log likelihood function, which is a distributed chi-squared function, the null hypothesis that all regressors in the model are zero is strongly rejected at the one-percent level in each of the three states (p-values are about 0.0001). Similarly, the Score and Wald statistics show that the combined regressors are very significant (with a p-value of 0.001). Results are also good for the Akaike (information) and Schwartz criteria, which adjust the log likelihood function for the number of observations and the number of regressors in the model. These two criteria are often used to assess model fit and model selection. Finally, the percent of concordant responses, used to determine the predictive ability of the model, is 65 percent, which is within the range of other studies. About 70 percent of the coefficients are statistically significant at the 1 percent level using the delete-a-group jackknife method (table 2).

Similar to previous adoption studies, several operator and farm variables were related to the likelihood of CRW Bt adoption. Both linear and quadratic coefficients were significant for operator's age (i.e., the linear term positive and quadratic term negative) implying that expected adoption increases with age only up to a point. This maximum was reached at slightly over 49 years. Similarly, both the linear and quadratic coefficients are significant for size, implying that expected adoption increases with size only up to a point. This maximum was reached at about 2900 acres (less than one-tenth of the size of the largest farm in the sample). In addition, operators who specialize in corn production were more likely to adopt CRW Bt, which may be an indication of their self-interest in keeping abreast of emerging production technologies peculiar to their primary commodity.

The perception of likely benefits and costs from the adoption of CRW Bt was reflected in the statistically significant signs on the CRW infestation and farm location variables. As expected, those farmers that are currently using insecticides to control the CRW as well as those that expect to incur a large yield loss in their fields are very significantly inclined to adopt CRW Bt. On the other hand, expected adoption is less likely in the eastern corn-belt where a larger portion of the crop is destined to the export market. While producers apparently recognize that there may be substantial pest control benefits from the use of CRW Bt, they may perceive some risks associated with marketing their crop, especially for producers in the Eastern corn-belt. Understandably, farmers who are familiar with a particular technology are inclined to adopt a related innovation. Farmers who had already adopted Bt corn to control the European corn borer were likely to adopt Bt corn to control the CRW.

Expected adoption was negatively related to off-farm work by the operator and spouse. A possible explanation of this result, which is counter to a previous study of actual adoption of herbicide tolerant soybeans, is that farmers and/or their spouses who work off the farm may be less informed about the new technology and thus are less inclined to adopt CRW Bt. Furthermore, information on CRW Bt, prior to the 2001 survey, may not have been easily accessible to producers with off-farm commitments.

Finally, the other variables in the analyses did not influence the likelihood of adopting CRW Bt. Expected adoption was not significantly related to the use of no-till practices, the use of continuous corn, or location of the farm on the new variant region. Surprisingly, and unlike many other studies, expected adoption was not significantly dependent on education. However, this technology may not require new skills or training since the new technology or trait is embodied in a familiar input (i.e., hybrid seed).

Concluding Comments

CRW is probably the most economically important corn insect pest. Farmers' options to manage CRW include crop rotation, insecticide use, and, as of 2003, Bt seed technology. Adaptation of the CRW to crop rotation has reduced farmer control options. Farm and operator characteristics such as age, education level, farm size and type, current technology use, current CRW infestation, geographic location, off-farm labor, and current CRW management practices provide insights into the technology adoption process. The ARMS provides the data needed for an in-depth analysis.

Thirty five percent of farmers reported that they were either likely or very likely to adopt Bt seed technology for CRW. Likelihood of adoption is positively related to both age and farm size, up to a point. The likelihood of adoption reaches a maximum at 49 years and at a farm size of about 2900 acres. Farmers who currently manage for CRW with insecticides or estimate a large loss without treatment were also more likely to adopt this technology. This is almost certainly because these farmers either have, or foresee, a CRW infestation problem. Farmers who manage European corn borer with Bt seed technology are also more likely to use this technology.

Specialized corn farmers (farms that derived more than 50 percent of value of production from corn) were also more likely to adopt Bt seed technology when it becomes available.

Farms that were located in the eastern corn-belt were less likely to adopt this new technology, possibly due to the high percentage of their production bound for the export market. Surprisingly, off-farm labor had a negative effect. This differs from previous findings regarding actual adoption patterns. Stated likelihood of adoption is less certain than actual adoption behavior. Differences between self-expected and actual adoption behavior merit further study.

Given that the 2001 ARMS survey asked about the likelihood of CRW Bt adoption and that this technology was only approved for commercial use in 2003, an analysis of actual adoption will need to await the next ARMS corn survey, scheduled for 2004.

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Table 1. Variable Definitions and Means

Variable	Definition	Mean
OP_AGE	Age of the operator, years	52.001
AGE_SQ	Square of the age of the operator	2856.2
HIGHPLUS	Education, dummy = 1 if operator has at least high school	0.8891
CORNFARM	Dummy=1 if corn represents more than 50 % of production	0.3705
SIZE	Size of the farm, thousand acres of corn	0.2039
SIZESQ	Size of the farm squared	0.1378
ROOTWORM	Dummy =1 if insecticide is used for CRW	0.1241
CRWLOSS	Expected CRW losses, bushels	5.5015
NEWVARIANT	Dummy =1 if farm is located in counties where new variant of CRW is able to survive crop rotation	0.0912
OFF_HOURS	Off-farm work, operator and spouse, hours per year	1454.6
CONTIN	Dummy = 1 if operation is on continuous corn	0.1367
BTDUM	Dummy = 1 if operation is using Bt corn for ECB	0.1767
NOTILL	Dummy = 1 if operation is using no till	0.1745
EAST	Dummy = 1 if farm is located in eastern corn belt where a larger share of the corn is exported and used for food.	0.2591
EXPTADOP	Expected adoption of Bt corn to control CRW (very likely=1, very unlikely=5)	3.3425

Table 2. Ordered Logit Results

A. Response Profile

Value of the dependent variable (EXPTADOP)		Frequency	%
1	Very Likely	240	15.12
2	Likely	313	19.72
3	Uncertain	397	25.02
4	Somewhat Unlikely	188	11.85
5	Very Unlikely	449	28.28
		1587	100.00

B. Association of Predicted Probabilities and Observed Responses

Percent Concordant	64.7
Percent Discordant	34.5
Percent Tied	0.8
Pairs	984223

C. Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
Akaike	943474.56	886808.59
Schwartz	943496.04	886905.25
-2 Log L	943466.56	886772.59

Testing global null hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	56693.9649	14	<.0001
Score	51218.1	14	<.0001
Wald	53173.8	14	<.0001

Probabilities modeled are cumulated over the lower ordered values.

Table 3. Maximum Likelihood Parameter Estimates - Ordered Logit Using the Jacknife Variance Estimator

Dependent variable: EXPTADOP

Variable	Parameter estimates	Standard error	t statistics
Intercept_1	-4.78351***	1.07580	-4.44646
Intercept_2	-3.51523***	1.08207	-3.24861
Intercept_3	-2.35819**	1.07627	-2.19108
Intercept_4	-1.77170	1.09953	-1.61132
OP_AGE	0.09302**	0.03836	2.42475
AGE_SQ	-0.00094***	0.00033	-2.83255
HIGHPLUS	0.08192	0.21165	0.38705
CORNFARM	0.50443***	0.17732	2.84480
SIZE	0.77356**	0.30536	2.53331
SIZESQ	-0.13358*	0.07127	-1.87425
ROOTWORM	0.62950***	0.13750	4.57808
CRWLOSS	0.01397**	0.00600	2.32738
NEWVARIANT	0.27528	0.28935	0.95136
OFF_HOURS	-0.00015***	0.00006	-2.71405
CONTIN	0.08727	0.19298	0.45224
BTDUM	1.23644***	0.12855	9.61839
NOTILL	0.04725	0.16475	0.28679
EAST	-0.55644***	0.14497	-3.83823

***, **, * Statistical significant coefficients at the 1 percent, 5 percent, and 10 percent significance levels, respectively.